

Page 1 **Concussion Defined**

“Concussion” is derived from the Latin word *concussus*, to shake violently. Concussion is a complicated injury that can present in a variety of ways. We are striving for, but have yet to achieve, a complete neurological and neurobehavioral understanding of concussion.

Forces that Produce Concussion

Video Excerpt from NET Television’s *Concussions: Heading for Change*

NARRATOR:

During linear acceleration, the head’s forward motion is stopped by a direct impact. Inside, the brain keeps moving, crashing into the skull. A lateral impact, like a cross-punch in boxing, can cause rotational acceleration where the brain spins on its axis.

Confusion about Concussions

Video

ARTHUR MAERLENDER: In the last decade we have found a tremendous amount of information about concussions. We’ve started to look at cognition. We started to look at balance. We started to look at other factors that are really important, that help us understand the recovery process.

The definition, um, itself is somewhat difficult because it’s based on subjective symptoms and your ability to say that you feel a particular way or not. Not every concussion is identified by watching somebody stumble around. And in fact, loss of consciousness is not even a necessary factor for a concussion.

The cultural, sort of social aspect of sports has always been about pushing and pushing through. And you’re actually trained to push through some pain. Unfortunately it gets to a point where we don’t recognize when there’s an injury and even can be critical of people who say they have an injury. Just shaking off the bell-ringer and going back in is not a very good strategy, in fact it could be life threatening in some cases. So, we’re really trying to protect athletes and individuals from those risks, so their brain can recover.

Concussion in Sports Definitions and Position Statements

The definitions gathered here have basic commonalities:

- A concussion is a brain injury that is transient — its effect is of relatively short duration.
- A concussion affects the functioning of the brain.

This might create the impression that a concussion is a “mild” injury, not worthy of much concern. However, concussion makes the brain vulnerable to further injury with serious, long-term consequences.

Although the concussion itself may be minor, the greatest risk comes afterward, depending on how the y is managed. You can’t prevent a concussion, but by managing a first concussion with rest and time to recover, you can prevent subsequent concussions and the serious risks they entail.

The **American Society for Sports Medicine** defines concussion as:

- A traumatically induced transient disturbance of brain function.
- Caused by a complex pathophysiological process.
 - Concussions are a subset of mild traumatic brain injuries (mTBIs).
 - All concussions are mTBIs, but not all mTBIs are concussions.

Harmon, KG *et al. Br J Sports med* 2013; 47:15-26

Position Paper

<http://www.ncbi.nlm.nih.gov/pubmed/23243113>

The **American Academy of Neurology** defines concussion as:

A clinical syndrome of biomechanically-induced alteration of brain function.

- Typically affects memory and orientation.
- May involve loss of consciousness.

Giza C, Kutcher J, et al. *Neurology*, 2013; 10.1212/WNL.0b013e31828d57dd.

Position Paper

https://www.aan.com/uploadedFiles/Website_Library_Assets/Documents/3Practice_Management/5Patient_Resources/1For_Your_Patient/6_Sports_Concussion_Toolkit/position.pdf

The **5th International Conference on Concussion in Sport held in Berlin 2016**

<http://bjsm.bmj.com/content/51/11/838>

The definition of concussion

The Berlin 2016 expert panel modified the previous CISC definition as follows:

Sport related concussion is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilised in clinically defining the nature of a concussive head injury include:

SRC may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head.

SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.

SRC may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.

SRC results in a range of clinical signs and symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases symptoms may be prolonged.

The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc) or other comorbidities (eg, psychological factors or coexisting medical conditions).

They further clarified the use of biometric devices for identifying head-force exposure (e.g., accelerometers):

“Although current helmet-based measurement devices may provide useful information for collision sports, these systems do not yet provide data for other (non-collision) sports, limiting the value of this approach. Furthermore, accelerations detected by a sensor or video-based systems do not necessarily reflect the impact to the brain itself, and values identified vary considerably between studies. The use of helmet-based or other sensor systems to clinically diagnose or assess SRC cannot be supported at this time”
p.2.

The **National Athletic Trainers Association Position Statement 2014** chose to use the American Academy of Neurology’s definition of concussion – a “trauma-induced alteration in mental status that may or may not involve loss of consciousness.”

NATA explained:

This definition was selected based on its broad application by medical organizations and widespread use within the literature. . . . Notably absent from the literature and consistent with previous recommendations were the terms *ding*, *getting one's bell rung*, *clearing the cobwebs*, and other such phrases. . . . These colloquial terms are antiquated, minimize injury severity, and should not be used to refer to concussion or mild traumatic brain injury.

Position Paper

http://www.nata.org/sites/default/files/Concussion_Management_Position_Statement.pdf

Page 2 **Facts & Myths**

Concussion ≠ Loss of Consciousness

Even if the trauma is not serious enough to result in a loss of consciousness (LOC), there can be cognitive, motor, and behavioral abnormalities.

Of the roughly 300,000 sports-related concussions per year treated in emergency rooms, only 8.9% involve loss of consciousness.

Not Just for Athletes

Concussions can happen to **any** active person, not just to athletes involved in formalized activity. Concussions can happen on the playground, in gym classes, on bike trails, in the home, or any place a person is engaged in physical activity.

Not Just a Bell Ringer

Because of the old *bell ringer* mindset (a perception that a person can “shake off” a head-jolting impact and play through or carry on with the activity), a concussion may go unreported and/or untreated. Slowly, the bell ringer mindset is becoming unacceptable. A concussion is never anything to be ignored. As a licensed health care professional, you can help advance this new line of thinking as you work with coaches, staff, parents or guardians, and other health care professionals.

A Concussion is a Concussion

At the end of the day, regardless of the force that caused it or the symptoms it produces, **a concussion is a concussion**. A concussion is an injury to the brain. It is never to be taken lightly.

Mild? Moderate? Severe?

A concussion is a brain injury. Telling a person he or she has a “mild” brain injury is comparable to telling a woman she is “mildly pregnant”. What you must bear in mind is that **brain injuries are not created equal**. Everyone responds differently. *Treating* a concussion is more important than *grading* it.

Page 3 **Brain Injuries**

There are levels of traumatic brain injury (TBI). A concussion is a form of *mild* traumatic brain injury. Though all concussions are mild TBIs, they can be categorized as simple or complex, depending on the combination and duration of symptoms.

With proper management, most concussions (*mild* TBIs) will resolve. However, a *moderate* or *severe* traumatic brain injury involves greater damage than can be adequately treated with concussion management.

Post Traumatic Amnesia

Levels of TBI

Mild (includes all concussions)

Glasgow Coma Scale* Post
Traumatic Amnesia
Loss of Consciousness
Recovery Time

13-15

Less than 1 day

0 to 30 minutes

"Simple" Concussion = Less than 14 days

"Complex" Concussion = 14 or more days

Moderate

Glasgow Coma Scale* Post
Traumatic Amnesia
Loss of Consciousness
Recovery Time

9 - 12

Between 1 and 7 days

Between 30 minutes and 24 hours

Some symptoms may resolve within 12

months; some may be permanent.

Severe

Glasgow Coma Scale*
Loss of Consciousness
Recovery Time

3 - 8

More than 7 days

More than 24 hours

Some symptoms may resolve within 12
months; some may be permanent.

Symptoms of Concussion

Whether simple or complex, concussions can involve an overlapping range of symptoms as well as varied duration and long-term effects.

Thinking / Remembering

- Difficulty thinking clearly.
- Feeling slowed down.
- Difficulty concentrating.
- Difficulty remembering new information.

Physical

- Headache.
- Fuzzy or blurry vision.
- Nausea or vomiting (early on).
- Dizziness.
- Sensitivity to noise or light.
- Balance problems.
- Feeling tired, having no energy.

Emotional / Mood

- Irritability.
- Sadness.

- More emotional.
- Nervousness or anxiety.

Sleep

- Sleeping more than usual.
- Sleeping less than usual.
- Trouble falling asleep.

General

As the Centers for Disease Control and Prevention states:
Some of these symptoms may appear right away, while others may not be noticed for days or months after the injury, or until the person starts resuming their everyday life and more demands are placed upon them. Sometimes, people do not recognize or admit that they are having problems. Others may not understand why they are having problems and what their problems really are, which can make them nervous and upset.

Source: CDC http://www.cdc.gov/concussion/signs_symptoms.html

*** Glasgow Coma Scale**

A rating scale used in the assessment of brain function, using numbers to represent degrees of responsiveness, such as eyes open, responds to commands, and so on. The higher the rating, the more responsive the patient. Lower ratings indicate greater damage and more severe injury.

Page 4 *Characteristics*

A concussion is a mild traumatic brain injury (mTBI) that interferes with the brain's normal functioning. It affects the brain's software — a functional disturbance. Research suggests there may also be a structural injury affecting the brain's hardware, though not detectable using current technology.

Concussion is a temporal issue. Different processes take place, some immediately (within a minute), others over time (over hours), and still others over extended time (over days).

This disturbance involved in concussion is a neurometabolic dysfunction (a mismatch between the brain's needs and the available resources) involving:

- Ionic fluxes — cellular changes in processing.
- Pathophysiologic events — abnormal phenomena.

This neurometabolic dysfunction precipitates an “energy crisis” in the brain, leading to multiple symptoms and a state of post-concussive vulnerability.

When a trauma occurs, the brain experiences an added need for glucose at the same time the body is shutting down systems to protect itself and as blood flow to the brain decreases. There is a mismatch between the brain's energy demands and the available energy resources. The brain is trying to recover and repair itself. However, what the body needs to do is not what the body is doing, and this mismatch causes vulnerability to more damage.

What Happens in a Brain with a Trauma
Video

Testing in rodent brains has shown a sequence of events that may well parallel what happens in human brains experiencing trauma.

Normally, a signal arrives at the neuron and travels down the axon to another cell. Neurotransmitters are released in an organized manner, triggering the next cell with a specific coded message.

But during an injury, necessary potassium ions rush out of the cell, and toxic calcium ions rush into the cell, leading to neurometabolic dysfunction. The brain is shutting itself down in an effort to repair, and in doing so, cuts off the supply of glutamate, a nerve cell messenger the brain needs in order to process the injury.

This neurometabolic dysfunction results in an energy crisis. Massive release of neurotransmitters interferes with cell communication. The nerve cell is extremely vulnerable in this condition. Further injury or stress may cause cell death or serious cell damage.

Recovery in humans can take hours or days. These automatic processes have been identified in animals, but it's likely the human processes are similar. We are still learning what to do about these processes and what residual damage may result.

Content: CDC and Nebraska Concussion Coalition

Page 5 *Epidemiology & Risks*

According to a 2007 study reported in the *Journal of Athletic Training*, sports are second only to motor vehicle accidents as the leading cause of traumatic brain injury in individuals ages 15 to 24. It's widely agreed that concussions and head injuries are under-reported.

The Nebraska Department of Health and Human Services surveyed head coaches in 2015. Results indicate concussion injuries affect young athletes across the state in a wide variety of sports.

Page 6 *The Problem*

Concussion = Internal Collision

Video Excerpt from NET Television's *Concussions: Heading for Change*

DENNIS MOLFESE: A concussion is some injury to the brain. We think the mechanism that produces it is mainly whiplash, so this rapid movement to the head back and forth or to the side, that perhaps is stretching some of the white matter tracks in the brain and that loses some communication between different brain areas.

This internal collision is hard enough on an adult brain. It seems to be even harder on the developing brain. New research shows that young athletes are especially vulnerable to the effects of concussion.

- Besides disrupting normal brain development, an initial concussion puts a youth at greater risk for repeat injury and subsequent disability.

- Some research estimates that 90% of subsequent concussions take place within ten days of the initial concussion because students return to regular activities before they are sufficiently recovered.
- Athletes, knowingly and unknowingly playing while symptomatic, leave the brain vulnerable to long-term neurological impairment and catastrophic injury, even death.

Brady Beran's Story

Video Excerpt from NET Television's *Concussions: Heading for Change*

NARRATOR: Brady Beran had a bright future. He excelled in academics and was an exceptional football and soccer athlete. At 16, Brady tied a Nebraska state soccer record with 13 consecutive shutouts as a goalie. He planned to play college soccer for Creighton University. But that all changed on September 24th, 2004.

TOM BERAN: He got hurt in the first quarter, and they had to come out and help him off, and he was out a few plays. Then he came back in, and after he played awhile, they made a comment to his best friend's mom. They said, "He's like a step slow."

BRADY BERAN: It was during the third quarter of the game, and I got hurt on a kickoff return. I was gonna go block someone over here, and then someone came over here and got me on the head, helmet-to-helmet collision. The coach came, helped me get up, 'cause I was slow getting up, and walk off to the sidelines. And then, once I got to the sidelines, I collapsed.

TOM BERAN: When I walked down there, his eyes were rolled back, and he'd started to foam at the mouth and stuff, and I didn't think he was gonna make it.

NARRATOR: Brady was rushed to the hospital where he immediately entered surgery to stop a brain bleed. The odds were stacked against him.

BRADY BERAN: I had less than a 10% chance of surviving surgery. The doctor had done this operation three times before, and none of those patients ever made it beforehand.

NARRATOR: Brady survived the surgery, but was placed in a medically-induced coma. The doctors hoped the coma would help his recovery within 48 hours.

CAROL BERAN: Then Monday comes around, and they take him off the coma medicine, and they tell us he should be waking up in eight to ten hours. Well, twelve hours later, he hadn't moved a muscle. And I asked the nurse, "What's going on?" She said, "That's not good."

NARRATOR: When Brady finally awoke from his medically-induced coma, five weeks had passed.

CAROL BERAN: The doctors never really told us what was going to happen. We just thought he'd wake up, and everything would be OK.

BRADY BERAN: It's not like you see in the movies, you know. When you come out of your coma, you're like, "Oh Mom, I missed you. How are you?" Nothing like that.

TOM BERAN: When the brain's involved, I still think we don't know that much about it. They kind of prepared us for, you know, they said he may never smile again. So, I mean, it was tough, let me tell you.

BRADY BERAN: One of the first things they do is to help me get to learn how to walk. It takes five people, one on each side of me holding me. Holding me up, making sure I don't fall down. And one person helping me move my right leg. The fourth person behind me pushing the wheelchair so if I needed to rest, I could sit down and rest. And then a fifth person in front of me saying, "Take a step with your left foot, take a step with your right foot." And the first time I made it up walking, I made it five steps. It was a pretty huge accomplishment for me.

NARRATOR: The rehabilitation process was long. Brady's drive to overcome the challenges ahead, surprised his doctors.

BRADY BERAN: They said I wouldn't be able to go to college. When I was in college, they didn't think I was gonna be able to graduate, even from a community college. I graduated from a community college. They didn't think I was gonna be able to handle a major university like UNL. I graduated from UNL, and then I've held, you know, two different full-time jobs while being married and just been yeah, just showing people what the human body can do and what a strong spirit can do is something that I enjoy doing.

Since 1945, over 510 brain injury fatalities have occurred in football. (Mueller, 2010) The highest incidence was recorded between 1965 and 1974, when 162 were reported. But fatalities have declined sharply since then due to implementation of rules to prevent spearing and other causative mechanisms.

In 2013, the Nebraska Department of Health and Human Services surveyed youth from the Nebraska Brain and Spinal Cord Injury Registry about concussions in sports, revealing some of their behaviors and beliefs regarding concussions. These youth had received medical treatment for and were identified as having concussions.

Page 7 *Multiple Injury Risks*

Undiagnosed

Video

LILY SUGHROUE, Living with Concussion After Effects:

The first concussion I had was in a basketball game. I was hit in the ear and dropped cold to the floor and was left there while the game continued. They said I didn't have a concussion because I didn't have a brain bleed, and that I would just go home and I was fine.

About two years after that, I had another concussion, and it was in a car accident. I ended up breaking out a window with my head not remembering anything that had happened. And they told me I still did not have a concussion because I had no brain bleed.

The next concussion was a bullying incident at school. I don't remember what had happened, something got thrown at my head.

After each one I just felt worse, and worse. The one that I remember the most feeling different, was definitely the first one. But because I was so sick and having so many issues after the second, third, and fourth one, the symptoms were kind of just something that I already been dealing with.

After a concussion, the injured person is more vulnerable to experience another concussion. If a subsequent concussion occurs while symptoms persist from an earlier concussion, evidence suggests this subsequent concussion may be worse and recovery will take longer. This can happen minutes, days, or weeks after the first concussion.

In rare instances — so rare that it is difficult to study -- the consequences can be catastrophic. This is the phenomenon known as Second Impact Syndrome. It is often discussed today in the context of concussion, but the term refers to the rare circumstances in which the second impact is thought to lead to cerebrovascular congestion resulting in brain edema and increased intracranial pressure.

Labels in the field are not applied consistently, and terms such as Second Impact Syndrome are sometimes misused to describe any second concussion.

That being said, however rare Second Impact Syndrome might be, it's clear that the victim of concussion has suffered an insult to the brain, and it's essential to avoid further insult of any kind. Evidence suggests the more concussions an individual suffers, the worse his or her subsequent concussions may be. The risk of additional injury is always present when concussion has occurred, in part because of its accompanying symptoms such as dizziness, blurred vision, and impaired thought-processing.

Though it is (fortunately) improbable that you will encounter true Second Impact Syndrome, the possibility of such tragic consequences underscores the importance of identifying concussion cases, providing proper treatment including mental and physical rest, and managing return to physical and mental activities so the patient is truly ready to play and learn.

Page 8 *After Effects*

Repeated “Bangs” are Bad Video

ARTHUR MAERLENDER, PhD, ABPP, Center for Brain, Biology, & Behavior Associate Director:
What we know and what we don't know are areas that people sometimes are surprised about. We don't know what the biological marker of the concussion is. We do know that it is a brain injury. We believe it is. We have every reason to believe it is by the response people have.

Having a bang on the head is not good and the more you get banged in the head, probably that that's not very good either. Particularly if you're not recovered from the first one.

But when it comes to, “how bad is it? How many times can you get hurt?” We really don't have specific numbers. That's where the research is trying to go. Is where, “How many is too many?” “When should you stop playing sports?” It's not clear yet.

Normally, concussion symptoms resolve in a matter of weeks. For sufferers of post-concussion syndrome (PCS), the thinking, behavioral, and emotional symptoms associated with their concussion fail to resolve and sometimes linger for up to a year after the injury.

A growing body of evidence indicates a high number of concussions can cause long-term memory impairment, emotional instability, erratic behavior, depression, problems with impulse control, and early onset neurodegenerative diseases.

Much research is still required to prove connections between concussions suffered in youth with neurodegenerative diseases later in life. One of the most serious and significant neurodegenerative diseases suspected of resulting from repeated concussions is chronic traumatic encephalopathy (CTE).

Chronic Traumatic Encephalopathy (CTE)

Chronic traumatic encephalopathy (CTE) is thought to be a progressive, neurodegenerative disease, caused by repeated blunt force impacts to the head. There is not yet a proven link between concussion and CTE, but CTE has been firmly linked to activity that subjects the brain to repeated acceleration and deceleration.

First reported in 1928, this phenomena was originally referred to as *Dementia Pugilistica* (or more commonly as “Punch Drunk Syndrome”) because it was believed to affect only boxers. The terms “traumatic encephalopathy” and “CTE” were first used in the 1960s. CTE has captured extensive popular attention in recent years as research increases to determine its relationship to and effect on athletes.

Tau is a toxic protein that takes the form of neurofibrillary tangles (NFTs) and neuropil threads (NTs) in areas of the brain. This abnormal protein initially impairs the normal functioning of the brain and eventually kills brain cells.

CTE is only diagnosed on autopsy and is associated with a history of memory disturbances, behavioral and personality changes, mood disorders, and/or dementia. However, there is no (yet) identified clinical phenotype to allow for diagnosis (Iverson et al, 2018). Since at this point, CTE can only be diagnosed by examining the brain after death, it is limited by the number of cases discovered thus far (since autopsies are not performed on all potential CTE victims). The research is in its infancy.

A review of CTE findings highlighted the following (Maroon et al, 2013):

- 153 case reports of CTE have found that a history of mTBI was the only risk factor consistently associated with CTE.
 - These are the reports of those diagnosed after autopsy;
 - There is no denominator - millions have been exposed;
 - It appears to be caused by brain trauma;
- In this systematic review, no relationships between CTE and age of death or abnormal ApoE allele (Maroon et al, 2015);
- In that study, suicide and the presence of premorbid dementia were not strongly associated with CTE.

“We conclude that the incidence of CTE remains unknown due to the lack of large, longitudinal studies. Furthermore, the neuropathological and clinical findings related to CTE overlap with many common neurodegenerative diseases. Our review reveals significant limitations of the current CTE case reporting and questions the widespread existence of CTE in contact sports.”

Maroon JC, Winkelman R, Bost J, Amos A, Mathyssek C, Miele V.; [Chronic traumatic encephalopathy in contact sports: a systematic review of all reported pathological cases.](#) PLoS

One. 2015 Feb 11;10(2):e0117338. doi: 10.1371/journal.pone.0117338. eCollection 2015.
Review. Erratum in: [PLoS One. 2015;10\(6\):e0130507](#).

Iverson, G.L., Keene, C.D., Perry, G. & Castellan, R.J. (2018). The Need to Separate Chronic Traumatic Encephalopathy Neuropathology from Clinical Features. *Journal of Alzheimer's Disease* 61, 17–28.